

# Snowpack enhancement by means of cloud seeding with Silver Iodide

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# Introduction

# Junta de Vigilancia del Río Cachapoal Primera Sección y sus Afluentes

- A private Water Surveillance Board
- We distribute Cachapoal's River irrigation water for about 120,000 acres
- Our members are Farmers, Hydroelectric Facilities, Mining companies and City Water distribution Company
- The total river water distribution is equivalent to:
  - Farmers: 3,500 cu.ft/s
  - Hidroelectricity: 8,600 cu.ft/s
  - Mining companies: 250 cu.ft/s
  - Rancagua and Machalí (cities): 36 cu.ft/s

# Programme Budget

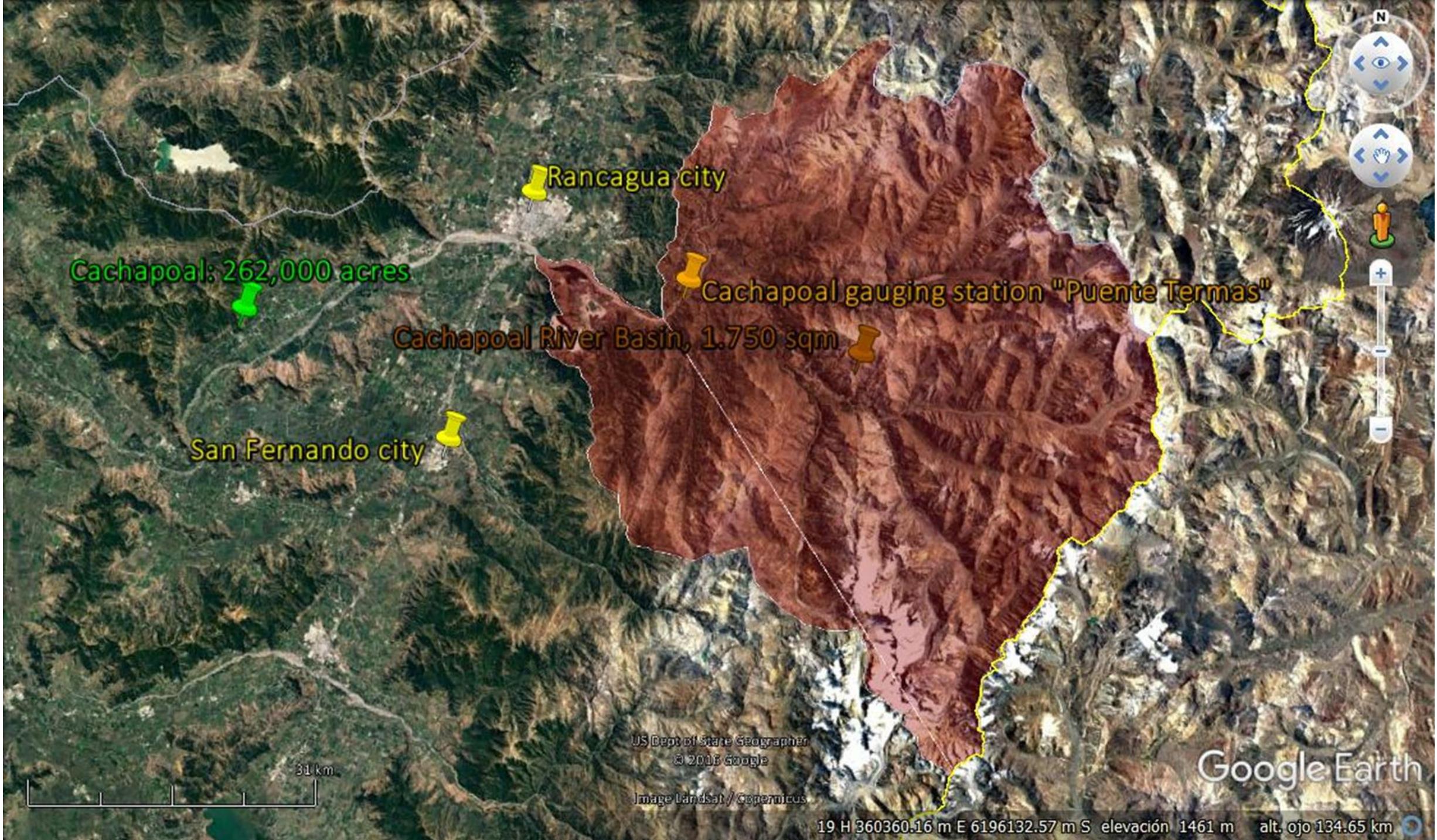
- US\$ 170,000 a year
- Joint venture between the Board, a mining Company (CODELCO - El Teniente, state-owned) and an hydroelectric Company (Pacific Hydro now owned by the Chinese government)
- Part of the equipment was provided by the state

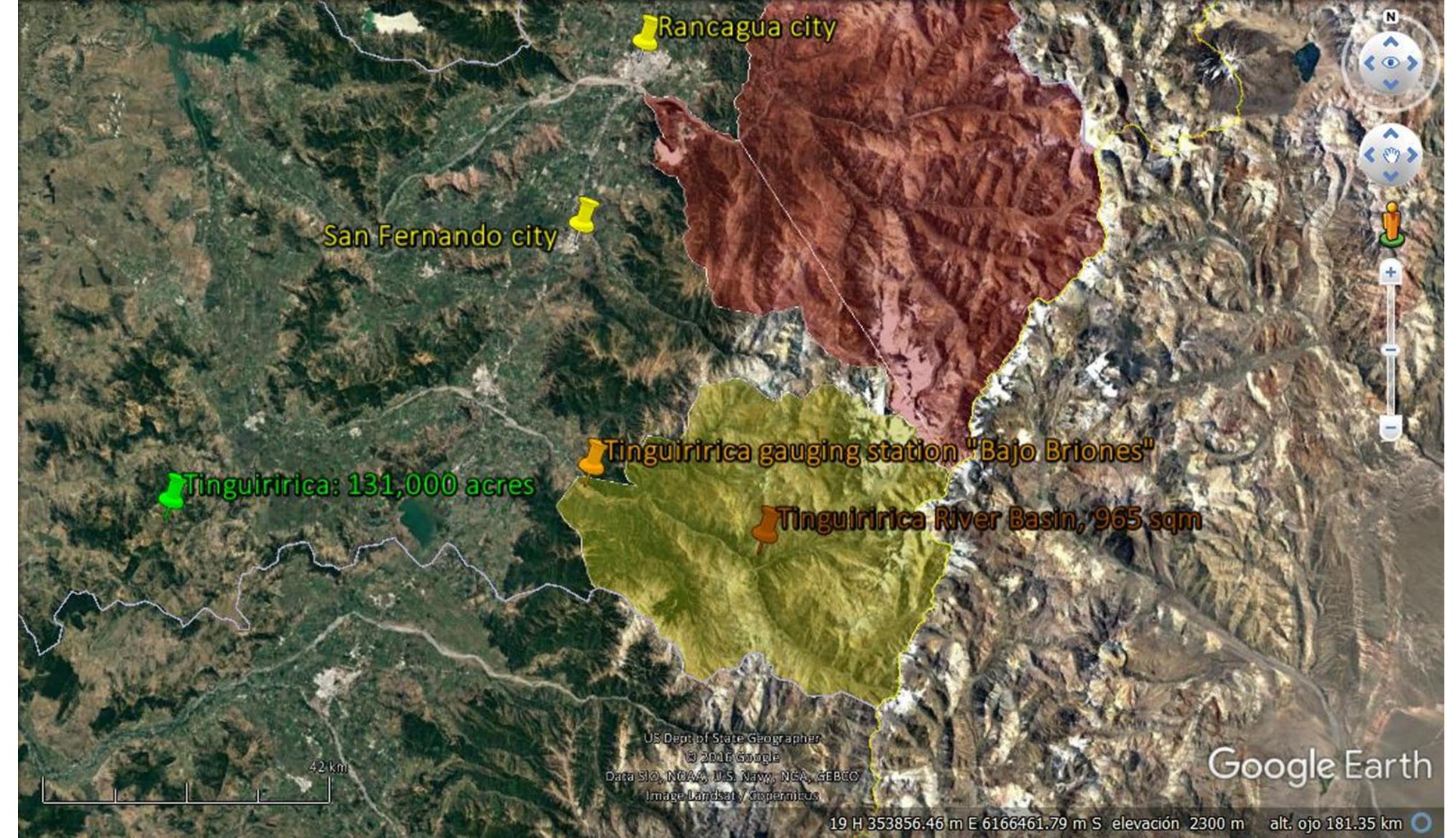


# General Information

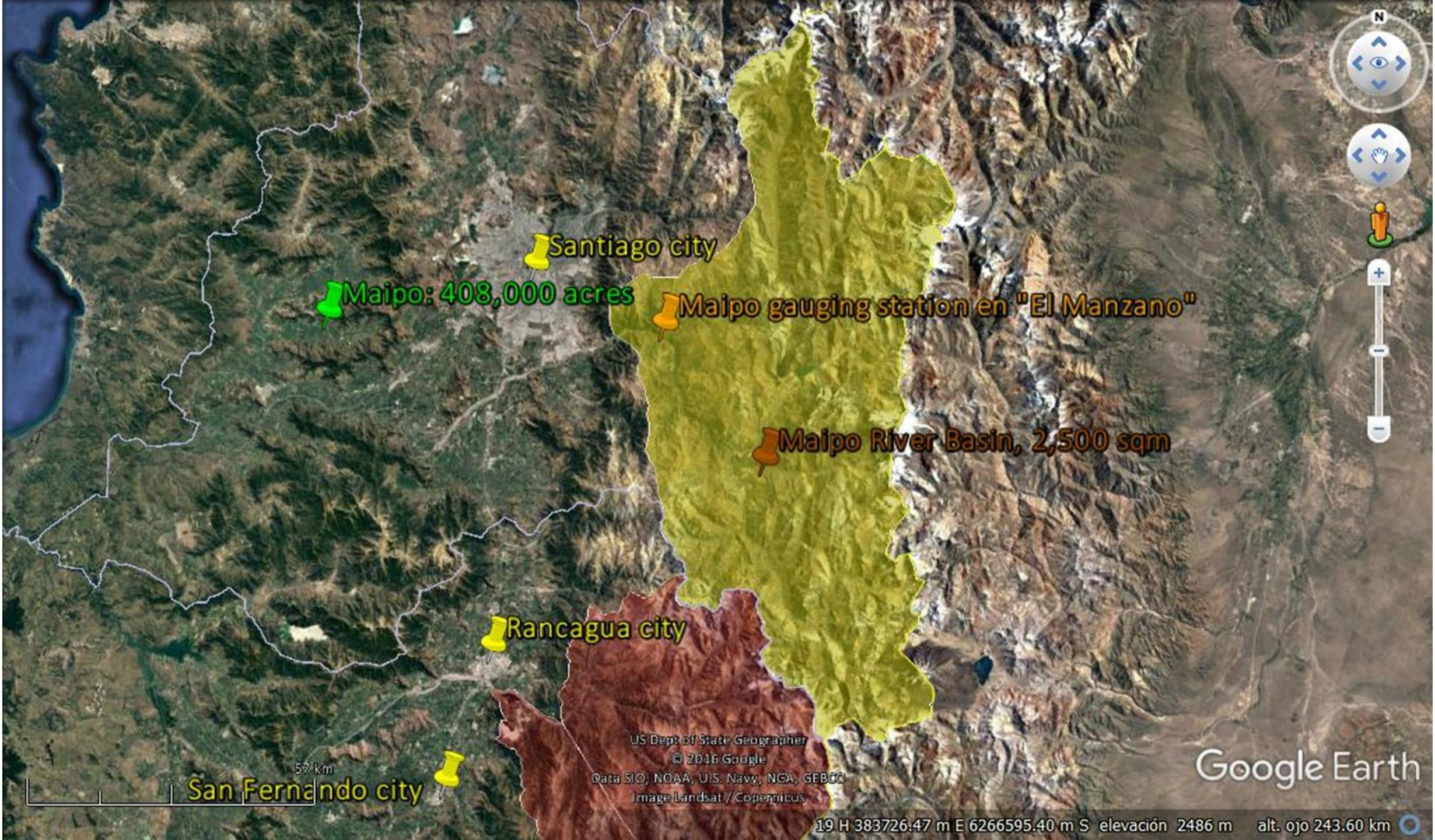
- Ground based AgI generators
- Releasing 0.25 oz/h (7.2 g/h)
- 100 hours per equipment (year average)
- 5 miles apart (average)
- 3.5 months
- Fired up to 12 times a year (average), 12 to 18 Precipitation events/year (Winter storms)
- All generators are remote control operated via GPRS o Satellite

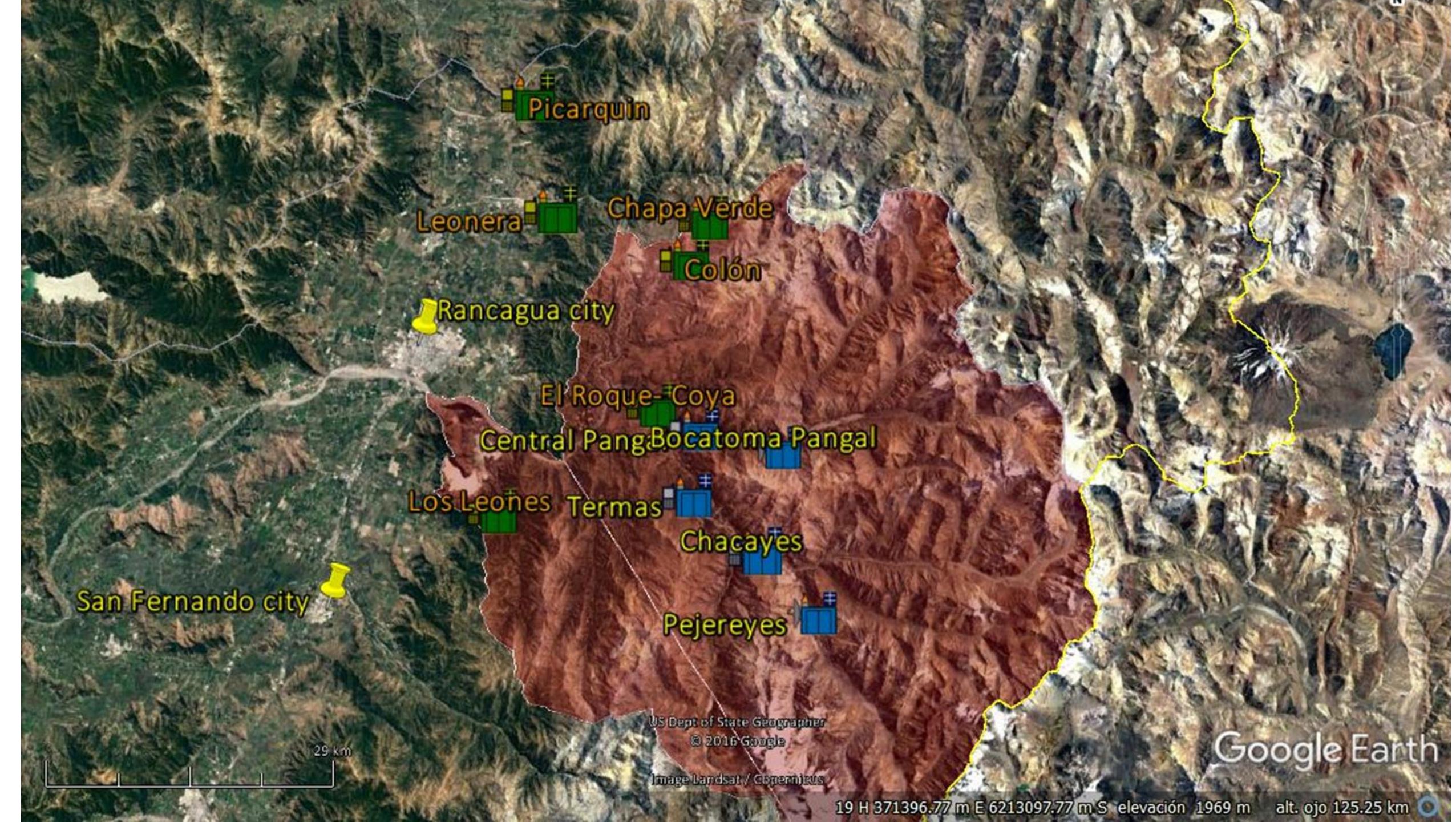






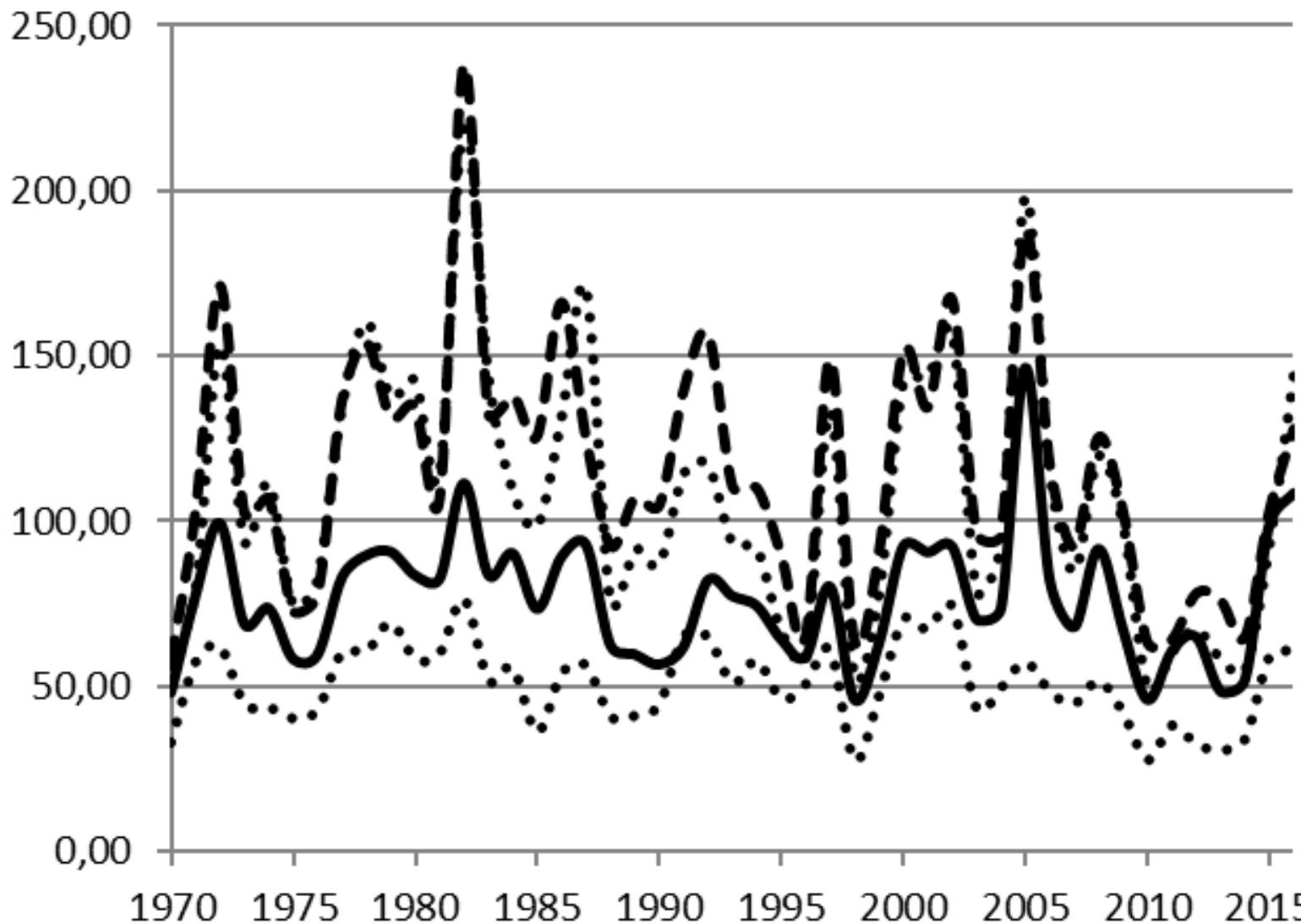
19 H 353856.46 m E 6166461.79 m S elevación 2300 m alt. ojo 181.35 km





# Annual Flows

## (m<sup>3</sup>/s)



Seding Period:  
Cachapoal 2000-2016

- Cachapoal
- Tinguiririca Los Briones
- Maipo Manzano
- Maipo La Obra

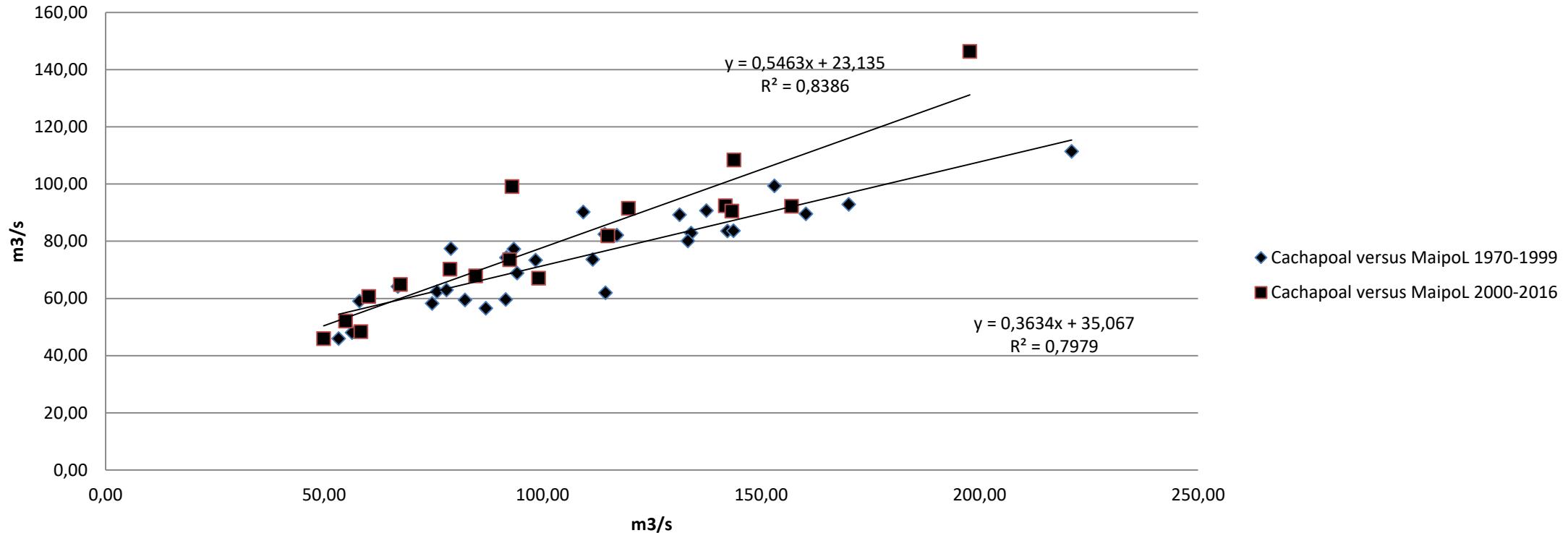
Flow ( $\text{m}^3/\text{s}$ ), simple ratios, double ratios & derived increases

	Octubre-Marzo (marzo año siguiente)					Abril-Septiembre					Oct-Sep (año)				
	1970-99	2000-16	R	$\Delta(\%)$	1970-99	2000-16	R	$\Delta(\%)$	1970-99	2000-16	R	$\Delta(\%)$			
Cachapoal	108.4	108.3	0.999	-0.1	41.1	47.3	1.15	15	74.7	79.6	1.07	7			
Tinguiririca	71.1	64.7	0.910	-9	33.4	30.8	0.92	-8	52.8	49.2	0.93	-7			
Maipo M	167.2	148.8	0.890	-11	69.8	65.0	0.93	-7	118.5	108.5	0.92	-8			
MaipoLaO	154.7	144.5	0.934	-6.6	63.5	57.1	0.90	-10	109.1	103.4	0.95	-5			
		RD	$\Delta(\%)$			RD	$\Delta (\%)$			RD	$\Delta (\%)$				
Cachapoal/Tinguiririca	$\frac{0.999}{0.910} = 1.10$	10				$\frac{1.15}{0.92} = 1.25$	25			$\frac{1.07}{0.93} = 1.15$	15				
Cachapoal/MaipoMzo	$\frac{0.999}{0.890} = 1.12$	12				$\frac{1.15}{0.93} = 1.24$	24			$\frac{1.07}{0.92} = 1.16$	16				
Cachapoal/MaipoLaO	$\frac{0.999}{0.934} = 1.07$	7				$\frac{1.15}{0.90} = 1.28$	28			$\frac{1.07}{0.95} = 1.13$	13				

## Linear correlations

	Octubre-Marzo	Abril-Septiembre	Oct-Sept (año)
Cachapoal-Tinguiririca	$r = 0.89$	$r = 0.81$	$r = 0.80$
Cachapoal- Maipo Mzo	$r = 0.89$	$r = 0.82$	$r = 0.87$
Cachapoal-Maipo La O	$r = 0.92$	$r = 0.78$	$r = 0.89$

**Figura #4: Cachapoal (y) versus Maipo La Obra (x)**  
**Octubre-Septiembre (anual)**



1970-1999:  $\langle \text{Cachapoal} \rangle = 0.3634 \langle \text{Maipo} \rangle + 35.07$ ;  $\langle \text{Maipo} \rangle = 109.13 \Rightarrow \langle \text{Cachapoal} \rangle = 74.73$

2000-2016:  $\langle \text{Cachapoal} \rangle = 0.5463 \langle \text{Maipo} \rangle + 23.14$ ;  $\langle \text{Maipo} \rangle = 103.38 \Rightarrow \langle \text{Cachapoal} \rangle = 79.61$

Y las razones:  $R_{\text{simple}}^{\text{Cachapoal}} = \frac{79.61}{74.73} \approx 1.07$ ;  $R_{\text{simple}}^{\text{Maipo}} = \frac{103.38}{109.13} \approx 0.95$ ;  $RD = \frac{1.07}{0.95} \approx 1.13$

# Final Conclusions

Apparent increases, derived from the double ratios for the arithmetic means, indicate the presence of a positive change signal for the Cachapoal river basin when compared to the flow of the Maipo river (better control).

***7% (October-March), 24% (April-September), and 13% (annual)***

2.- The use of arithmetic differences of the same guide flows to apparent increases in:

***22% (October-March), 56% (April-September), and 31% (annual)***

3.- Correlation-regression models using arithmetic means corroborate the values presented, but also clarify that the modification signals should be understood as a property of the series, while for individual values this signal can be hidden by noise (the high variability).

The operations of seeding winter clouds for the Cachapoal river basin have positively modified the natural precipitation regime.

# Other analysis

- Reasons from the statistical mean
- Bootstrapping
- Comparison of power spectra

Thanks for Listening